CONCENTRATION ESTIMATES AT NORTHSHORE ROAD TO MEET WATER QUALITY STANDARDS IN LAS VEGAS BAY

Prepared For:

Nevada Division of Environmental Protection
Carson City, Nevada

By:

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3716 Greencrest Drive
Las Vegas, Nevada 89121

Report No.: 94/03/03
March 1994

DRAFT FOR REVIEW AND COMMENT ONLY

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Administrator

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DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
DIVISION OF ENVIRONMENTAL PROTECTION
Capitol Complex
333 W. Nye Lane
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APR 1 - 1994
C.C.S.D. GEN

April 15, 1994

Jim Gans
Clark County Sanitation District
5857 E. Flamingo Rd.
Las Vegas, NV 89122

Dear Mr. Gans:

Enclosed for your information is a copy of the draft report entitled "Concentration Estimates at Northshore Road to Meet Water Quality Standards in Las Vegas Bay" prepared by Richard French. At this point, the report is in draft form and any comments you or your staff may have would be appreciated. I plan on scheduling a meeting with the City, the County, Henderson and Richard French to discuss the results of the report.

Also enclosed is a copy of the proposed change to the 4-day average un-ionized ammonia water quality standard for Lake Mead. As a result of USEPA revising the acute to chronic ratio for un-ionized ammonia in the national criteria, we are proposing to change the existing 4-day average standard from 0.04 mg/l to 0.05 mg/l un-ionized ammonia. A Public Hearing of the State Environmental Commission has been scheduled for 9:30 am on May 26, 1994 at the West Charleston Branch of the Clark County Public Library located at 6301 W. Charleston. This water quality standard revision along with some revisions to the toxics standards for metals are scheduled to be on the agenda. We are not proposing any other changes to the water quality standards for Lake Mead at this time.

If you have any questions, please contact me at 687-4670 extension 3098 or Adele Basham of my staff at 687-4670 extension 3102.

Sincerely,

Wendell D. McCurry, P.E., Chief
Bureau of Water Quality Planning

Enclosures
cc: David Paulson
Robin Bain

PROPOSED PERMANENT REGULATION OF THE NEVADA STATE ENVIRONMENTAL ([illegible]ISSION

SS: (FYA)
P- review this & prepare a 1 p. summary comments
cc: EJC, RB, PM
Thank you.
7-22

EXPLANATION - Matter underlined is new: matter in [ ] is material to be omi

AUTHORITY: NRS 445.201 and 445.244

Section 1. Chapter 445 of the NAC is hereby amended by [illegible]s set forth as section 1 of this regulation.

445.1353 Lake Mead from the western boundary of Las Vegas Marina Campground to the confluence of Las Vegas Wash. Control point at the Western Boundary of Las Vegas Marina Campground.

	WATER QUALITY STANDARDS		
PARAMETER	REQUIREMENTS TO MAINTAIN EXISTING HIGHER QUALITY	WATER QUALITY STANDARD FOR BENEFICIAL USES	BENEFICIAL USE
Temperature °C ΔT Single Value[a]	0	2	Warmwater fishery.[b]
pH - Standard Unit Single Value	95% of samples not to exceed 8.9	Within Range 7.0 - 9.0	Wildlife propagation.[b] agricultural use. warmwater fishery.aquatic life. industrial supply.
Dissolved Oxygen-mg/l Single Value in 90% of Samples	--	$\geq$5 mg/l	Warmwater fishery.[b] aquatic life. stock watering. noncontact sports. noncontact sports & esthetics. wildlife propagation.
Nitrogen Species as N-mg/l Single Value in 90% of samples	Total Inorganic Nitrogen $\leq$5.3	Nitrate $\leq$90	Warmwater fishery.[b] stock watering. wildlife propagation.
Single Value	--	Nitrite $\leq$10	Stock watering.[b] wildlife propagation.[b]
Un-ionized Ammonia as N -mg/l	--	c	Warmwater fishery.[b] aquatic life[b].
Total Dissolved Solids - mg/l			Stock watering.[b] irrigation.
Single Value	e	$\leq$3000	
Suspended Solids - mg/l Single Value	--	$\leq$25	Warmwater fishery.[b] aquatic life. esthetics.
Turbidity - NTU Single Value	d	$\leq$25	Warmwater fishery.[b] aquatic life. esthetics.
Fecal Coliform MV 100 ml Single Value	--	g	Agricultural use.[b] wildlife propagation[b] noncontact sports & esthetics.

[a]Maximum allowable increase in temperature above water temperature at the boundary of an approved mixing zone.

[b]The most significant beneficial uses.

[c]The 4-day average for the concentration of un-ionized ammonia must not exceed [0.04] 0.05 mg/l more often than once every 3 years. The daily value for this average must consist of the average of the data collected from not less than 3 sites within a cross section of Station 2 that are representative of the top 2.5 meters of the cross section, and must account for diurnal fluctuation. This average is not applicable to the area between Station 2 and the confluence of the Las Vegas Wash. The single value must not exceed 0.45 mg/l more often than once every 3 years. When the temperature exceeds 20°C, these standards must be adjusted pursuant to methods accepted by the United States Environmental Protection Agency. "Station 2" means the center of the channel at which the depth is 10 meters.

[d]Turbidity must not exceed that characteristic of natural conditions by more than 10 Nephelometric Unites.

[e]Any increase in Total Dissolved Solids must not result in a violation of the standards specified in "1981 Review--Water Quality Standards for Salinity, Colorado River System," approved by the state environmental commission on June 8, 1982.

[f]The Commission recognizes that because of discharges of tributaries that localized violations of standards may occur in this reach.

[g]Any discharge from a point source into Las Vegas Wash must not exceed a log mean of 200 per 100 ml, based on a minimum of not less than five samples taken over a 30-day period nor may more than 10 percent of the total samples taken during any 30-day period exceed 400 per 100 ml.

The "Guidelines for Formulating Water Quality Standards for the Interstate Waters of the Colorado River System," adopted January 13, 1967, are incorporated as a supplement to the standards for this stream. The guidelines may be obtained from the division of environmental protection at no cost.

(Added to NAC by Environmental Comm'n, eff. 11-22-82; A 12-17-87)

MEMORANDUM

FILE: NPDES-CENTRAL PLANT EFFLUENT DISCHARGE PERMIT

Clark County Sanitation District

E. JAMES GANS
DIRECTOR

TO: PUNDA PAI, PROJECT ENGINEERING SUPERVISOR

FROM: STAN SHUMAKER, PROJECT ENGINEER SS

SUBJECT: WATER QUALITY STANDARDS

DATE: MAY 13, 1994

Dave Paulsen, Doug Karafa and I spent over 1½ hours yesterday discussing the letter and report from NDEP's Water Planning Chief concerning Lake Mead water quality standards. Doug Karafa will carry the discussion to today's SWAC meeting, and letters will be drafted to respond to the complex issues raised.

- A letter supporting the Nevada Environmental Commission's proposed change to the un-ionized ammonia standard in the Nevada Administrative Code <u>should</u> be mailed or presented at the May 26, 1994 Public Hearing.

- A separate letter addressing concerns with the document, "Concentration Estimates at Northshore Road to Meet Water Quality Standards in Las Vegas Bay," prepared by Richard French, <u>must</u> be mailed to the Water Planning Chief. The document is poorly written in an unscientific manner, misrepresents lab data and the capabilities of the District's lab, and "concludes" that total phosphorous and total ammonia concentrations in the Wash, measured at Northshore Road, must be reduced to meet Lake Mead water quality standards. If NDEP accepts this report, it follows that they will lower the TMDL's and WLA's in the District's next NPDES permit. The report would support cutting the phosphorous loading and the ammonia loading by 50%!

SS:tlm

cc: E. J. Gans
Bill Mahorney
Dave Paulsen
Doug Karafa

C:\DATA\STAN\WTRSTNDS.MEM(TLM)

DAN SZUMSKI & ASSOCIATES
CONSULTING ENGINEERS

June 16, 1994

Mr David Paulsen
Laboratory Services Supervisor
Clark County Sanitation District
5758 East Flamingo Road
Las Vegas, NV 89122-5501

Re: Review of: Concentration Estimates at Northshore Road to Meet Water Quality Standards in Las Vegas Bay, R French, March,'94,[DRAFT]

Dear Mr Paulsen:

I am in reciept of the above referenced draft report. I understand that this methodology will form the basis of NDEP's waste load allocations for Las Vegas Bay. Thank you for the opportunity to review and comment on it.

Technical comments

The report presents estimations of target ammonia and phosphorous loading to Lake Mead to achieve compliance with the NDEP's water quality standards for un-ionized ammonia, a toxicant, and chlorophyll 'a' as an indicator of phytoplankon productivity and eutrophication onset. The underlying methodology is contained in a 1988 report to NDEP by the author of the current study. I have not been able to locate a copy of that report in my files. I have, however, taken the time to re-derive Dick's equation and some other useful representations of the Las Vegas Bay hydraulics. These are provided in Attachment A.

The dilution model is a simple mass balance between two hydrodynamic features of the Las Vegas Bay system: inflow of clean Colorado River dilution water in the Lake's epilimnion, and upward mixing from the submerged density plume formed when Las Vegas Wash enters the Lake. The analysis makes the following assumptions:

1. The three flow quantities: Colorado River dilution flow [Q_b], vertical plume mixing [Q_z], and the flow balanced quantity [Qs] are independent quantities.

2. North Shore Road concentration is a good representation of the concentration in the wastewater plume and the vertical mixing flow. [i.e. there is no initial dilution where the Wash enters the Lake.]

3. The processes represented in the model are stationary.

It is also understood that the operative dilution ratio computed by this model is a hydrologic-dilution, or flow-dilution, rather than the concentration-dilution normally refered to in water quality planning. More precisely, a computed dilution of 25.0 implies that the concentration balance provided as input data, required 25 parts of dilution water, Qb, to each part of vertically mixed plume water, Qm, entrained in the surface layer. These are nebulous, and difficult to estimate quantities. The concentration dilution, by contrast, expresses the concentration dilution where-in 25:1 dilution implies that a concentration of 1.00 mgNH_3-N/l will dilute to 0.04 mgNH_3-N/l. This distinction is important in interpreting the model output and in understanding what the model is capable of telling us about allowable loading to Las Vegas Bay.

My interpretation of the dilution equation in Attachment A shows that it relates plume concentration and background concentration to segment concentration [where the water quality standard applies] by neglecting the consequent recycle effect. This allows computational facility at the expense of realistic representation. For example, the dilution equation that results when the recycle flow is included in the model is partially developed on page 3 of the attachment. It is recursive and cumbersome, and not at all well suited to water quality planning.

The best dilution ratio that I know of is the historical concentration dilution:

$$D = c_w / c_s$$

where: c_w is the NSR concentration
c_s is the segment concentration

This form of the dilution equation has two advantages:

1. It is a direct calculation of the aggregate concentration dilution observed in the past, and it is directly applicable as a predictive tool for estimating North Shore Road target values.

2. It is simple to operate and easy to understand.

It is also a direct measure of the operative quantity in the wastewater allocation process, c_w.

It has disadvantages similar to those in the flow-dilution form, in that it contains, in implicit form, all of the dilution process that are not explicitly stated in the equation. This means that the models sensetivity to most of these factors is indeterminate. I have done some calculation of concentration-dilution values and found them to be similar but lower than the flow-dilution quantities shown in the report. In addition, the grouping shows slightly lower variance.

Discussion

There is a lot of variability in the computed flow-dilutions both between variables, and along the temporal axis. This occurs because there are many factors influencing 'total dilution' regardless of weather it is expressed as flow- or concentration-dilution. For example the concentration of un-ionized ammonia is altered between North Shore Road and Station BC-2. Kinetic factors, such as transformation of $NH4^+$ to NH_3, phytoplankton utilization of NH_4^+, or ammonia stripping, occur. Transport phenomena cause mixing with more dilute lake water, and other plume mixing phenomena. Temperature and pH impart both long term trend and short term variance into the computed dilution. In addition, there are a host of other small scale randomizing factors that contribute to the final dilution. These are inplicit in both the flow- and concentration-dilution forms of the equation and are assumed to be representative of conditions into the future. In other words: the computed dilution values are total dilution quantities, irregardless of how the apparent dilution occured.

Neither equation is better than the other. They are both merely black box representations of very complex and difficult to dis-aggregate natural processes. From the standpoint of computing target concentrations at North Shore Road, both appear to be comparable relationships between c_w and c_s, and either might be employed in future allocation estimations. The advantage in the concentration-dilution form is interpretive; the computed quantity directly relates the target concentration to the inflow concentration at North Shore Road.

One final comment on these models is appropriate. These are not mass balance calculation. Even though the flow-dilution form is derived from a mass balance equation, the final target concentration at North Shore Road is independent of Las Vegas Wash discharge rate. In other words, the model allows that concentration at twice or three times the current flow rate. This obviously is not very valid. Therefore, this analysis method must be updated frequently to incorporate the most recent influences of factors in the prototype that the model recognizes only implicitly. Factors such as:

- Wash discharge rate,
- background concentration, and
- long term variations in temperature and lake level.

It is this need to continually update these dilution models, and the inability of such a model to extrapolate to conditions that have not yet been measured, that leads us to use deterministic mathematical models as water quality planning tools. For if, as is the case for Las Vegas Bay, the computed dilution is not stationary [def: exhibiting constant mean and variance in time], then the planning horizon that the model can be asked to address is only 2-4 years in the future if you're willing to tolerate errors of perhaps 50% [see trend in computed dilution in Table 1/pg 8]. This may be an adequate regulatory tool, since regulatory review is on a short cycle. But any kind of long term planning of the kind that CCSD and the City of Las Vegas must do, requires mathematical models that also allow long term estimatation. Here the planning questions have time horizons 20 to 50 years in the future, and the result is analysed as 'best estimates of the maximum or minimum effect' or 'optimistic and pessimistic projections of water quality' for a trial planning senario. The operative rule being: capital expenditure should follow long term trends rather than short term fluctuations in the environment.

These models can also be used to analyse the shorter term regulatory questions. In fact, the current WASP water Quality model does extremely well at computing dilution during either of the two time periods for which it has been calibrated. It might be interesting to re-compute the target concentrations at North Shore Road using that model for comparison.

Editorial comments

1. The report is not consistent in the units employed to express concentration. For example, The tables throughout the report express phosphorus concentration as mg total phosphate/l, or mg PO_4/l, while in other places, such as Figure 2, the words 'total phosphorus' as in mgP/l appear. The units ought to be explicitly stated whereever they occur in the report. I assume that all the nitrogen measurements are expressed as mg NH_T-N/l [where: NH_T is total ammonia].

I hope that this review of Dick's report is helpful to you. Please call me if you require further clarification of my report, or have questions in this regard. My office number is 916-777-6118.

Respectfully submitted,

Daniel S. Szumski

CONCENTRATION ESTIMATES AT NORTHSHORE ROAD TO MEET WATER QUALITY STANDARDS IN LAS VEGAS BAY

Prepared For:

Nevada Division of Environmental Protection
Carson City, Nevada

By:

Richard H. French, Ph.D., P.E.
3716 Greencrest Drive
Las Vegas, Nevada 89121

Report No.: 94/03/03
March 1994

DRAFT FOR REVIEW AND COMMENT ONLY

EXECUTIVE SUMMARY

The goal of this assignment was to estimate the target concentrations of total phosphorus and ammonia at North Shore Road that would result in the Las Vegas Bay water quality standards for chlorophyll a and un-ionized ammonia being met. The dilution ratio model (French, 1988) and stochastic simulation (French, 1988) were used to achieve this goal.

The results of the modeling effort are as follows:

1. Comparison of the data from the period 1991-1993 with data from the period 1985-1987 demonstrate that the primary time series used in the dilution ratio and stochastic simulation models are not stationary. Therefore, periodic re-evaluation of the target concentrations of total phosphorus and ammonia at North Shore Road to meet the water quality standards on Las Vegas Bay is warranted.

2. Use of data from the 1991-1993 period, results in the following target concentrations at North Shore Road to meet current water quality standards for chlorophyll a and un-ionized ammonia in Las Vegas Bay:

   Total Phosphorus

Critical Period April - September

Target Concentration = 0.32 mg/l

Critical Period July - September

Target Concentration = 0.28 mg/l

Total Ammonia

Critical Period April - September

Target Concentration = 0.67 mg/l

In comparison, the target North Shore Road concentrations presented in French (1988) were 0.64 mg/l for total phosphorus and 1.43 mg/l for total ammonia.

If the water quality standard for un-ionized ammonia was increased from 0.04 mg/l to 0.05 mg/l at Station BC-2, then the use of data from the 1991-1993 period would result in the following target concentration for total ammonia at North Shore Road:

Total Ammonia

Critical Period April - September

Target Concentration = 1.25 mg/l

3. One water quality standard on Las Vegas Bay relates to the concentration of chlorophyll a and this standard is translated to a target concentration of total phosphorus concentration at North Shore Road using a regression relationship that assumes the concentration of chlorophyll a is phosphorus limited. The City of Las Vegas has questioned the validity of this relationship. Although the question is valid, the resources for this assignment were not adequate to address this question.

4. The results of the study were impacted by the detection limits of the Clark County Sanitation District laboratory for total ammonia. That is, the current detection limit for total ammonia is 0.4 mg/l which is an order of magnitude larger than the water quality standard for un-ionized ammonia on Las Vegas Bay. A lower laboratory detection limit for total ammonia would likely result in a greater target concentration at North Shore Road.

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1. INTRODUCTION

The estimation of Las Vegas Wash (LVW) mass loadings of phosphorus and total ammonia to meet the water quality standards in Las Vegas Bay (LVB) requires that the hydrodynamics of the LVW-LVB interaction be modeled. In this report, the conservation of mass and statistical models used in 1988 (French, 1988) are used to estimate the concentrations of total phosphorus and total ammonia at North Shore Road (NSR) that will meet the water quality standards for chlorophyll a (assuming a previously developed relationship between chlorophyll a and total phosphorus was and remains valid) and un-ionized ammonia in LVB using new data. These results are compared with the results presented in French (1988).

It is the premise of this study and previous studies (French, 1988) that LVB water quality is controlled by the mass loading of LVW to LVB, and the amount and direction of mixing that occurs between the LVW inflow and the epilimnetic waters of LVB. While the LVW mass loading can be controlled by administrative action, the hydrodynamic interaction between LVW and LVB and their direction and magnitude are controlled by nature and are beyond the control of administrative action. Given that the models used by French (1988) tacitly assume that all conditions are stationary in time, it is reasonable that the situation be revisited periodically to examine whether concentration estimates from previous analyses remain valid.

The reader is referred to French (1988) for a description of the conservation of mass model used in this study. In Section 2 of this report, the phosphorus (TPO4) approach used is described and in Section 3, the total ammonia (TNH) analytic approach is described. In Section 4 of this report, generic conclusions are stated and briefly discussed.

2. TPO4 ANALYTIC APPROACH

The current water quality standard for chl a at LVB Station BC-3 reads in part

> "Mean summer (July-September) chlorophyll a shall not exceed 40 ug/l. The 4 year mean of summer means shall not exceed 30 ug/l."

The chl a standard is translated to a total phosphorus (TPO4) concentration at LVB Station BC-3 by a linear regression relationship developed by the Nevada Division of Environmental Protection (NDEP), Cooper (1988).

The TPO4-chl a regression equation developed by Cooper (1988) was based on data collected at LVB Stations BC-3, BC-4, and BC-5 during 1979-1987, Figure 1. Data from Station BC-2 were not used because of possible light and nitrogen limitations at this site. The data were also screened to remove data that could be considered to be nitrogen limited (TN:TP < 10). This screening procedure removed 12 of the 267 available data points, and only one of the points removed was in the period 1985-1987. The data used in this analysis are plotted in Figure 2, and the regression equation relating chl a and TPO4 is

Figure 1: Las Vegas Wash and Las Vegas Bay sampling station locations.

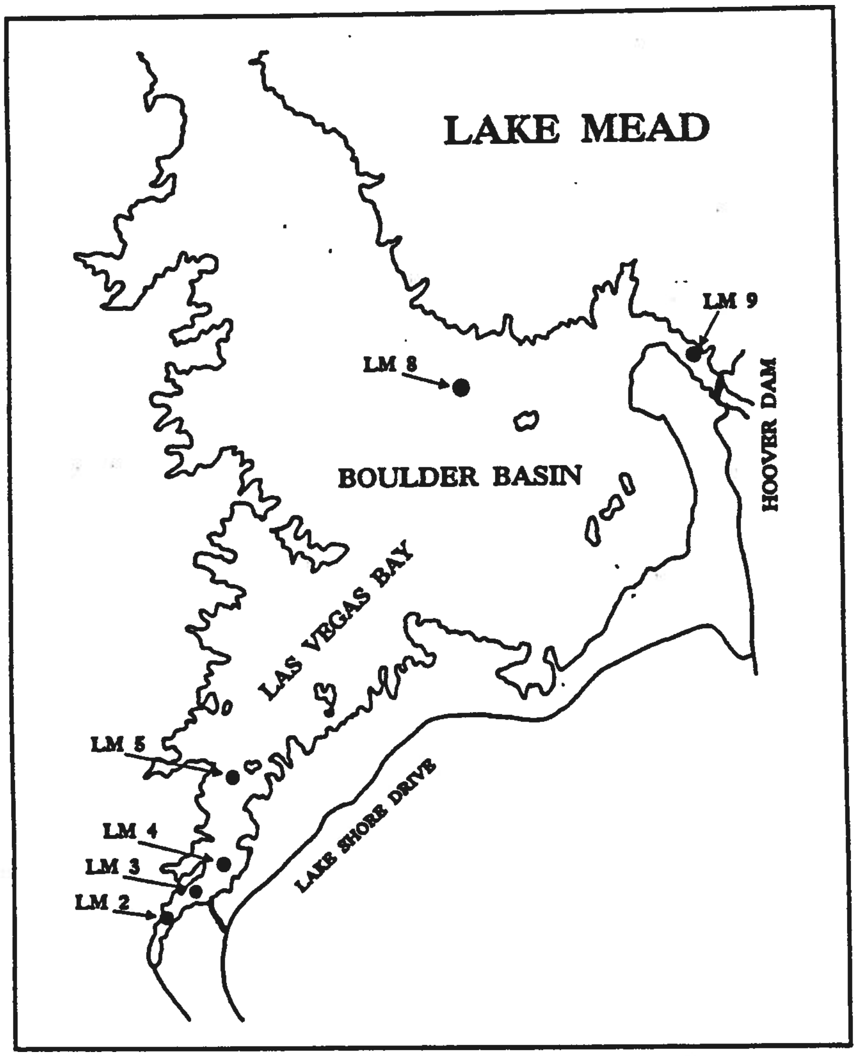
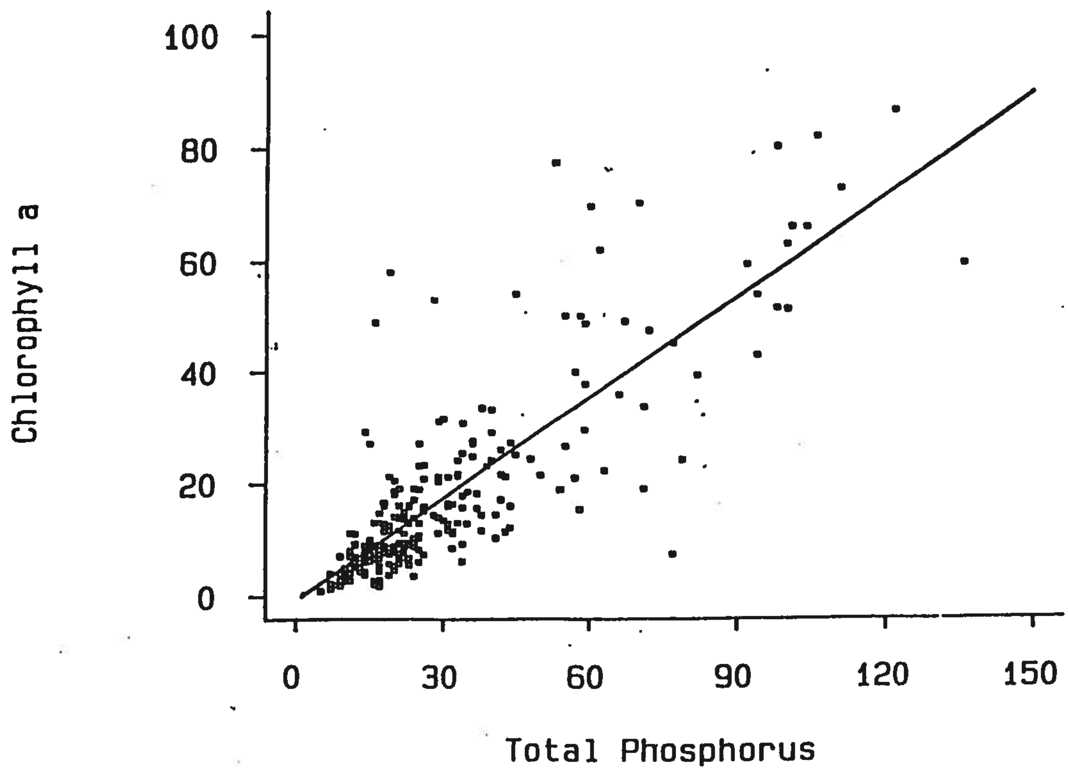


Figure 2: Regression of chl a as a function of total phosphorus for LVB, Cooper (1988).



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$$(\text{chl } \underline{a}) = 0.603(\text{TPO4}) - 0.704 \qquad (1)$$

with a correlation coefficient of 0.83 and where TPO4 = concentration of total phosphorus in (ug/l) and chl a = concentration of chlorophyll a in (ug/l).

Solution of Equation (1) for a long-term mean chl a concentration of 30 ug/l at station BC-3 yields a summer mean total phosphorus concentration of 0.051 mg/l, Cooper (1988). Although regression equations such as Equation (1) vary from lake to lake, Equation (1) is similar to the chl a - TPO4 relationships developed for other lakes; see for example, Dillon and Rigler (1974) and Jones and Bachmann (1976). The City of Las Vegas has raised questions regarding whether algal growth in Lake Mead is nitrogen or phosphorus limited. The relationship developed by Cooper (1988) assumes a phosphorus limitation; and the scope of work for this study was based on the assumption that this relationship was and remains valid.

In this application, the following interpretation of the existing water quality standard is used:

1. The allowable average TPO4 concentration at LVB Station BC-3 to meet the chl a water quality standard is 0.051 mg/l. Further, this allowable average TPO4 concentration

is the arithmetic average of concentrations at the thalweg and stations north and south of the thalweg (centerline) location.

2. For each month during the period April-September (inclusive), the available TPO4 data for LVB Station BC-3 are averaged yielding monthly averaged values. The period April-September is used because of the critical effect on summer chl a concentrations caused by spring injections of nutrients into the epilimnetic waters of LVB. The results when only the prescribed regulatory period (July-September) is used are also summarized in Table 1 and discussed.

3. For each year, the monthly average values of TPO4 are averaged for the period April-September (inclusive) yielding a "yearly" (critical period) average value. The July-September period averages are also used to estimate a "yearly" (critical period) average value.

4. Four "yearly" (critical period) average values of LVB Station BC-3 values of TPO4

Table 1: Summary of BC-8 (background station) TPO4 concentrations and dilution ratio values for TPO4/Chl a analysis. The complete 6-years of data available are summarized.

Month (1)	1985 c_b (mg/l (2)	1985 D (3)	1986 c_b (mg/l) (4)	1986 D (5)	1987 c_b (mg/l) (6)	1987 D (7)	1991 c_b (mg/l) (8)	1991 D (9)	1992 c_b (mg/l) (10)	1992 D (11)	1993 c_b (mg/l) (12)	1993 D (13)	6-Year Average (1985-1993) Avg c_b (mg/l) (14)	6-Year Average (1985-1993) Sig c_b (mg/l) (15)	6-Year Average (1985-1993) Avg D (16)	6-Year Average (1985-1993) Sig D (17)	3-Year Average (1991-1993) Avg c_b (mg/l) (18)	3-Year Average (1991-1993) Sig c_b (mg/l) (19)	3-Year Average (1991-1993) Avg D (20)	3-Year Average (1991-1993) Sig D (21)
4	0.020	29.6	0.012	36.0	0.009	11.7	0.012	16.5	0.005	15.0	0.020	4.6	0.013	0.006	18.9	11.7	0.012	0.008	12.0	6.5
5	0.017	17.8	0.010	13.2	0.008	22.3	0.012	4.4	0.012	8.9	0.010	3.4	0.012	0.003	11.7	7.5	0.011	0.001	5.6	2.9
6	0.024	10.8	0.008	23.7	0.008	17.7	0.014	17.0	0.012	4.3	0.010	8.9	0.013	0.006	13.7	7.0	0.012	0.002	10.1	6.4
7	0.007	20.9	0.007	8.1	0.008	10.7	0.009	9.6	0.013	3.3	0.010	----	0.009	0.003	10.5	6.4	0.011	0.002	6.4	4.5
8	0.006	16.2	0.009	7.3	0.008	8.3	0.012	5.2	0.016	7.0	0.010	----	0.010	0.003	8.8	4.3	0.011	0.001	6.1	1.3
9	0.006	30.6	0.006	22.3	0.009	12.3	0.008	7.5	0.010	8.8	0.010	63.0[1]	0.008	0.002	16.3	9.9	0.009	0.001	8.2	0.9
April-September, Inclusive, Average Values and Standard Deviations																				
mu	0.013	21.0	0.009	18.4	0.008	13.8	0.011	10.0	0.011	7.9	0.012	5.62	0.011	-----	13.3	----	0.011	-----	8.1	---
sig	0.008	7.8	0.002	11.0	0.001	5.2	0.002	5.5	0.004	4.2	0.004	2.89	0.002	-----	3.8	----	0.001	-----	2.5	---
July-September, Inclusive, Average Values and Standard Deviations																				
mu	0.006	22.6	0.007	12.6	0.008	10.4	0.010	7.4	0.013	6.4	0.010	----	0.009	-----	11.9	----	0.010	-----	6.9	---
sig	0.001	7.3	0.002	8.4	0.001	2.0	0.002	2.2	0.003	2.8	0.000	----	0.001	-----	3.9	----	0.001	-----	1.1	---

[1] Value not considered.

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are averaged, and it is this value that cannot exceed 0.051 mg/l TPO4.

In Table 1, the monthly average concentrations of TPO4 at Station BC-8 (the background station) and the dilution ratio (D) are summarized for two periods of time - 1985-1993 with the years 1988-1990 missing and 1991-1993. For comparative purposes, monthly average values of the background station concentration and the dilution ratio for the period 1985-1987 are summarized in Table 2. The detailed data for the period 1991-1993 on which Table 1 is based are contained in Appendix 1 in Tables 1.1-1.3; and the data on which Table 2 is based is contained in Appendix 1 in Table 1.4.

The current water quality standard is based on a four year average value; however, the limited data available (6-years) preclude a standard statistical analysis. Therefore, an approach involving stochastic simulation is used; and in this approach the following assumptions apply:

1. D and c_b are normally distributed random variables with the mean values and standard deviations summarized in Tables 1 and 2.

2. The data in Tables 1 and 2 are not biased.

3. The distributions of D and c_b are stationary in time. This assumption has been violated in the past and may be violated in the future. For this reason, in Table 1 two periods of time are summarized (1985-1993) with the years 1988, 1989, and 1990 missing and (1991-1993); and the data for a third period (1985-1987) from French (1988) are summarized in Table 2.

4. The data summarized in Tables 1 and 2 can be used to simulate monthly average values which are then used to simulate yearly (April - September and July - September) average values. These "yearly" average values are used to estimate the target allowable 4-year average values at NSR.

5. The running 4-year average values can be combined to estimate a target TPO4 concentration at NSR, and the standard deviation associated with this value.

Computer codes (Appendix 4 contains an example computer code listing) were developed to perform the stochastic simulations and 100-years of record was simulated. The results of this simulation were used as follows.

The <u>current</u> water quality standard for chl <u>a</u> states that the

Table 2: Summary of BC-8 (background station) TPO4 concentrations and dilution ratio values for TPO4/Chl a analysis for the period 1985-1987.

Month	Avg. D	Sig D	3-year Average (1985-1987) Avg. c_b (mg/l)	Std. Dev. c_b (mg/l)
4	25.8	12.6	0.011	0.005
5	17.8	4.55	0.010	0.004
6	17.4	6.46	0.010	0.006
7	13.2	6.75	0.008	0.002
8	10.6	4.85	0.008	0.003
9	21.7	9.16	0.007	0.002

April-September, inclusive, Average Values and Standard Deviations

mu	17.8	----	0.009	-----
sig	5.5	----	0.002	-----

July- September, inclusive, Average Values and Standard Deviations

mu	15.2	----	0.008	-----
sig	5.8	----	0.001	-----

standard will never be exceeded. From an engineering viewpoint, "never" is interpreted to mean that the target value of TPO4 will have only a 1% chance of exceedance each year at Station BC-3. The 97 four-year average values of target TPO4 concentrations that resulted from the stochastic simulation described above and summarized in Tables 3a and 3b; and from these the target TPO4 concentrations values at NSR that will satisfy the <u>current</u> water quality standard are estimated by

$$mu_{NSR} - z(sig_{NSR}) = \text{Target NSR TPO4 concentration (mg/l)}$$

and when z is taken as 2.4 which corresponds to an exceedance probability of 0.01

$$mu_{NSR} - 2.4(sig_{NSR}) = \text{Target NSR TPO4 concentration (mg/l)}$$

The results of the simulation and analysis described above are summarized in Tables 3a and 3b. These results demonstrate that the target TPO4 concentrations at NSR are influenced by both the yearly and monthly periods over which the input variables and parameters are averaged. As noted above, a stationary time series must be assumed; and this suggests that the "best" target values are given by the estimates deriving from the 1991-1993 period. It is noted that the target concentration values decrease as the averaging period expands forward from 1985. This decrease suggests that conditions affecting the hydrodynamic interaction of LVW and LVB continue to change.

Table 3a: North Shore Road (NSR) TPO4 target concentrations based on 100-years of simulation for various periods of parameter averaging. The critical period for modeling is taken as April - September, inclusive.

	Averaging Period		
	1985-1987	1985-1987 and 1991-1993	1991-1993
Target Mean Value (mg/l)	0.79	0.60	0.38
Standard Deviation	0.057	0.064	0.027
Target Value for non-Exceedance of Standard (mg/l)	0.65	0.45	0.32

Table 3b: North Shore Road (NSR) TPO4 target concentrations based on 100-years of simulation for various periods of parameter averaging. The critical period for modeling is taken as July - September, inclusive.

	Averaging Period		
	1985-1987	1985-1987 and 1991-1993	1991-1993
Target Mean Value (mg/l)	0.72	0.57	0.35
Standard Deviation	0.078	0.091	0.030
Target Value for non-Exceedance of Standard (mg/l)	0.53	0.35	0.28

3. UN-IONIZED AMMONIA ANALYTIC APPROACH

The current water quality standard for chronic un-ionized ammonia in Las Vegas Bay at Station BC-2 reads in part:

> The 4-day average concentration of un-ionized ammonia shall not exceed more often than once every three years 0.04 mg/l."

As before, French (1988), it is assumed that if the chronic un-ionized ammonia standard is met then the acute un-ionized ammonia standard will also be satisfied. The un-ionized ammonia standard also indicates that diurnal fluctuations of un-ionized ammonia in the top 2.5 m of water must be taken into account.

The historic data previous to 1987 at Las Vegas Bay Station BC-2 were taken at various times throughout the day, and therefore, in the previous study, the first step was to develop a technique for reducing the un-ionized data available previous to 1987 to daily average values. The study undertaken and the methodology developed is documented in French and Cooper (1989). This work determined that in Las Vegas Bay the daily average fraction of un-ionized ammonia (fui) occurred at approximately 1300 Pacific Daylight Time (PDT); the maximum at approximately 1600 (PDT); and the minimum at approximately 0800 (PDT). It is assumed that all data collected since the results of this study were published were taken at a time such that the daily average of fui could be computed.

In Table 4, the monthly average concentrations of total ammonia at Station BC-8 (the background station) and the dilution ratio (D) are summarized for two periods of time - 1985-1993 with the three years 1988-1990 missing and 1991-1993. For comparative purposes, monthly average values of the background station concentration and the dilution ratio for the period 1985-1987 are summarized in Table 5. The detailed data for the period 1991-1993 on which Table 4 is based are contained in Appendix 2 in Tables 2.1-2.3.

Un-ionized ammonia is the nitrogen species upon which the water quality standard is set; and therefore, the fraction of un-ionized ammonia (fui) must be estimated. Emerson et al (1975) provided the following equation for estimating fui as a function of water temperature and pH or

$$fui=1./(1 + 10^{((0.0902\text{-}pH) + 2730/(273.2 + T))}) \qquad (2)$$

where T = water temperature in degrees Centigrade. This equation does not take into account the effects of the concentration of total dissolved solids which is a factor; see for example French and Cooper (1989). In this analysis, it is assumed that the effect of total dissolved solids on the value of fui is not significant because TDS did not change significantly over the period of time involved.

Table 4: Summary of BC-8 (background station) total ammonia concentrations and dilution ratio values for the un-ionized ammonia analysis. The complete 6-years of data available are summarized.

Month	Year 1985		1986		1987		1991		1992		1993		6-Year Average (1985-1993)				3-Year Average (1991-1993)			
	c_b (mg/l)	D	c_b (mg/l)	D	c_b (mg/l)	D	c_b (mg/l)	D	c_b (mg/l)	D	c_b (mg/l)	D	Avg c_b (mg/l)	Sig c_b (mg/l)	Avg D	Sig D	Avg c_b (mg/l)	Sig c_b (mg/l)	Avg D	Sig D
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
4	0.018	27.8	0.047	9.8	0.011	9.5	0.200	3.4	0.200	11.2	0.200	5.9	0.113	0.096	11.3	8.6	0.200	0.000	6.8	4.0
5	0.015	8.3	0.036	33.5	0.011	7.4	0.506	5.2	0.200	13.1	0.200	11.5	0.161	0.191	13.2	10.4	0.302	0.177	9.9	4.2
6	0.013	12.6	0.030	19.0	0.010	25.4	0.200	3.1	0.200	20.5	0.200	107.	0.109	0.100	31.3	37.9	0.200	0.000	43.5	55.6
7	0.022	20.8	0.027	27.7	0.011	18.9	0.451	11.9	0.200	62.8	0.200	8.5	0.152	0.171	25.1	19.7	0.284	0.145	27.7	30.4
8	0.019	19.8	0.011	21.9	0.010	27.9	0.200	40.5	0.200	136.	0.200	53.5	0.107	0.102	49.9	44.0	0.200	0.000	76.7	51.8
9	0.018	35.3	0.013	32.5	0.012	42.7	0.200	26.4	0.200	54.9	0.200	----	0.107	0.102	38.4	10.9	0.200	0.000	40.6	20.2
mu	0.018	20.8	0.027	24.1	0.011	22.0	0.293	15.1	0.200	49.8	0.200	37.3	0.125	-----	28.2	----	0.231	-----	34.2	---
sig	0.003	9.8	0.014	9.0	0.001	13.1	0.145	15.2	0.000	47.6	0.000	43.6	0.025	-----	14.9	----	0.048	-----	25.8	---

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Table 5: Summary of BC-8 (background station) total ammonia concentrations, dilution ratio values, and fui values for un-ionized ammonia analysis. The period 1985-1987 is summarized.

Month	3-Year Average (1985-1987)					
	Avg D	Sig D	Avg c_b (mg/l)	Sig c_b (mg/l)	Avg fui	Sig fui
(1)	(2)	(3)	(4)	(5)	(5)	(6)
4	15.7	10.4	0.025	0.019	0.126	0.100
5	16.4	14.8	0.021	0.013	0.191	0.026
6	19.0	6.4	0.018	0.011	0.331	0.120
7	22.5	4.6	0.020	0.008	0.301	0.065
8	23.2	4.2	0.013	0.005	0.290	0.123
9	36.8	5.3	0.014	0.003	0.167	0.043
mu	22.3	---	0.019	-----	0.234	-----
sig	7.8	---	0.004	-----	0.083	-----

In Table 6, the monthly average values of fui are summarized for two periods of time - 1985-1993 with two years 1988-1990 missing and 1991-1993. The pH and temperature data on which Table 6 is based is contained in Tables 3.1 through 3.6 in Appendix 3.

The un-ionized ammonia water quality standard is based on a four day average value of the concentration of un-ionized ammonia; however, the available data base does not contain sufficient consecutive 4-day periods of data to allow a traditional statistical analysis. As before, French (1988), stochastic simulation is used (code listing in Appendix 5), and the following assumptions are used:

1. D, c_b (Station BC-8), and fui are normally distributed random variables for the critical season (April - September, inclusive). These variables have the monthly means and standard deviations summarized in Table 6.

2. The data summarized in Table 6 are not biased. As noted previously, the total ammonia data for the years 1991-1993 likely skew many of the average values used in the analysis.

3. The distributions of D, c_b, and fui are stationary over the periods used in the analysis.

4. The data summarized in Table 6 can be used to estimate target daily average concentration of total ammonia at NSR. These target daily average values can then be combined to estimate target 4-day running average values that can be combined to estimate target critical period concentrations.

conjecture; random variable, chance

A computer code was developed to perform the stochastic simulation and 100-years of record was simulated. The critical calculation in the code - the target daily average value of total ammonia at NSR was

$$TNH = (0.04/fui)(D + 1) - Dc_b \qquad (3)$$

where TNH = target concentration of total ammonia at N

At this point, it is appropriate to note that by the terminology "target minimum average NSR concentration" the following computational and data selection process is indicated. During each yearly critical period, there are 183 days; and thus, 183 daily average values of total ammonia. After four day averages are formed, there are 180 values for the critical period. From each of the 100 critical periods simulated, the minimum concentration that will satisfy the water quality standard was found. This set of 100 values is normally distributed; and therefore, the target

Table 6: Summary of the fraction of un-ionized ammonia (fui) at Station BC-2 for the period 1985 through 1993.

Month	1985	1986	1987	1991	1992	1993	6-Year Average (1985-1993)		3-Year Average (1991-1993)	
	fui	fui	fui	fui	fui	fui	Avg	Sig	Avg	Sig
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
4	0.240	0.055	0.083	0.027	0.096	0.035	0.089	0.078	0.060	0.035
5	0.175	0.177	0.221	0.055	0.132	0.117	0.146	0.058	0.101	0.041
6	0.467	0.240	0.286	0.088	0.150	0.158	0.232	0.135	0.132	0.038
7	0.226	0.345	0.332	0.185	0.264	0.211	0.260	0.066	0.220	0.040
8	0.172	0.418	0.281	0.260	0.197	0.207	0.256	0.089	0.221	0.034
9	0.186	0.118	0.198	0.104	0.166	0.083	0.142	0.047	0.118	0.043
mu	0.244	0.226	0.234	0.120	0.168	0.135	0.188	-----	0.142	-----
sig	0.113	0.137	0.089	0.087	0.058	0.070	0.071	-----	0.065	-----

concentration at NSR such that the concentration of un-ionized ammonia at Station BC-2 will only exceed 0.04 mg/l once in 3 years is:

$$mu_{NSR} - z(sig_{NSR}) = \text{Target NSR } \overset{TNH}{\cancel{TKN}} \text{ concentration (mg/l)}$$

and when z is taken as 0.44 which corresponds to an exceedance probability of approximately 3 years.

$$mu_{NSR} - 0.44(sig_{NSR}) = \text{Target NSR } \overset{TNH}{\cancel{TKN}} \text{ concentration (mg/l).}$$

When reviewing the results in Table 7a, several observations are relevant:

1. The target ~~TKN~~ TNH concentrations at NSR are influenced by the yearly periods over which the input variables and parameters are averaged. This was noted in Section 2 of this report in relation to the target TPO4 values at this location.

2. A second problem with the analysis derives from the laboratory ~~TKN~~ TNH detection limits for the period 1991-1993. In this time period, the detection limit for ~~TKN~~ TNH was 0.40mg/l (Salas, 1994). When the laboratory reported concentrations at or below detection a concentration of

one-half the detection limit or 0.20mg/l was used. Previous to the 1991-1993 time period, the ~~TKN~~ TNH detection limits were apparently lower; and therefore, the data for this period are skewed high relative to earlier time periods. The importance of this problem can be demonstrated by a simple numerical example. If fui has a value of approximately 0.15 (Table 6) and the ~~TKN~~ TNH concentration is 0.40mg/l then the concentration of un-ionized ammonia is approximately 0.06mg/l. If fui has a value of approximately 0.15 and the ~~TKN~~ TNH concentration is taken as 0.20mg/l, then the concentration of un-ionized ammonia is 0.03mg/l.

2. Comparison of the results in Table 7a with the corresponding results in French (1988) demonstrate a difference in results. This is an artifact of how the input data were averaged. That is, in French (1988) all the data, regardless of month, were averaged while the current computational code averages the month and then the year. This is a computational anomaly that has no significant affect on the results.

At this point, let us assume that the regultory standard for un-ionized ammonia at Station BC-2 is changed to 0.05 mg/l. The results for such a change, using all the same modeling procedures,

are summarized in Table 7b. All of the foregoing discussion also applies to the results presented in Table 7b.

Table 7a: North Shore Road (NSR) ~~TKN~~ TNH target concentrations based on 100-years of simulation for various periods of parameter averaging. The critical period for modeling is taken as April - September, inclusive. The regulatory standard for un-ionized ammonia at Station BC-2 is 0.04 mg/l.

	Averaging Period		
	1985-1987	1985-1987 and 1991-1993	1991-1993
Target Mean Value (mg/l)	1.88	0.76	0.80
Standard Deviation	0.20	0.21	0.30
Target Value for non-Exceedance of Standard (mg/l)	1.70	0.67	0.67

Table 7b: North Shore Road (NSR) ~~TKN~~ TNH target concentrations based on 100-years of simulation for various periods of parameter averaging. The critical period for modeling is taken as April - September, inclusive. The regulatory standard for un-ionized ammonia at Station BC-2 is 0.05 mg/l.

	Averaging Period		
	1985-1987	1985-1987 and 1991-1993	1991-1993
Target Mean Value (mg/l)	2.42	1.41	1.25
Standard Deviation	0.26	0.36	0.45
Target Value for non-Exceedance of Standard (mg/l)	2.30	1.25	1.05

4. CONCLUSIONS

At this point, there are a number of observations and comments should be brought to the attention of the reader; and these are follows:

1. This analysis assumes a stationary time series. The results presented in this report clearly indicate that the time series involved are not stationary and continue to change. That is, between 1985 and 1993, the dilution ratios associated with both total phosphorus and ammonia have significantly decreased. This decrease has resulted in lower target concentrations of these compounds to meet water quality standards in Las Vegas Bay. Given that the time series of the primary variables are not stationary, the "best" estimates of target concentrations to meet Las Vegas Bay water quality standards are those deriving from using the most recent data.

2. The dilution ratio is a lumped parameter; that is, its value incorporates the effect of all hydrodynamic, chemical and biological processes. Therefore, without a complete comparison of data from the period 1985-1987 and 1991-1993, the reason or reasons that the time series are not stationary cannot be identified.

3. **The total ammonia detection limits of the Clark County Sanitation District laboratory have a significant impact on the target concentrations of total ammonia at North Shore Road.**

4. **There may be differences in sampling protocols between the 1985-1987 and 1991-1993 periods that have an unknown effect on the modeling results.**

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APPENDIX 1

Table 1.1: The TPO4 (total phosphorus) data summarized in this table derive from the raw data for the relevant months provided by the City of Las Vegas and the Clark County Sanitation District for 1991. Note, error notations were not provided with the data base; and therefore, the notations used in 1992 are applied. In this table, the cross sectional average values of the concentration of TPO4 at Station BC-3 (LVM-3) are computed and used to estimate dilution ratio coefficients.

1991

Date (1)	TP04 NSR (mg/l) (2)	TP04 BC-8e (mg/l) (3)	TP04 BC-3Ce (mg/l) (4)	TP04 BC-3Ne (mg/l) (5)	TP04 BC-3Se (mg/l) (6)	TP04[1] BC-3e Avg (mg/l) (7)	D (8)
040291	0.915	-----	0.000?	0.082	0.000?	0.027	
040891	-----	0.008	0.099	0.089	0.117	0.102	
041591	0.860	-----	0.000?	0.000?	0.000?	0.000	
042291	-----	0.015	0.054	0.080	0.043	0.059	
042991	0.940	-----	0.000?	0.000?	0.000?	0.000	
mu[1]	0.905	0.012	0.076	0.084	0.080	0.063	16.5
sig[1]	0.041	0.005	0.032	0.005	0.052	0.038	
050791	-----	0.013	0.254	0.066	0.149	0.156	
051391	0.650	-----	0.000?	0.000?	0.000?	0.000	
052091	-----	0.010	0.046	0.054	0.047	0.049	
052891	0.350	-----	0.000?	0.000?	0.000?	0.000	
mu[1]	0.500	0.012	0.150	0.060	0.098	0.102	4.42
sig[1]	0.212	0.002	0.147	0.008	0.072	0.076	
060391	-----	0.008	0.063	0.059	0.061	0.061	
061091	-----	-----	0.000?	0.000?	0.000?	-----	
061191	0.937	-----	-----	-----	-----	-----	
061791	-----	0.019	0.060	0.058	0.071	0.063	
062491	0.820	-----	0.000?	0.000?	0.000?	-----	
mu[1]	0.878	0.014	0.062	0.058	0.066	0.062	17.0
sig[1]	0.083	0.008	0.002	0.001	0.007	0.001	
070191	-----	0.010	0.080	0.070	0.103	0.084	
070891	0.840	-----	0.000?	0.000?	0.000?	-----	
071591	-----	0.009	0.082	0.061	0.091	0.078	
072291	0.700	-----	0.000?	0.000?	0.000?	-----	
073091	-----	0.009	-----	-----	-----	-----	
mu[1]	0.770	0.009	0.081	0.066	0.097	0.081	9.57
sig[1]	0.099	0.001	0.001	0.006	0.008	0.004	
080591	0.660	-----	0.000?	0.000?	0.000?	-----	
081291	-----	0.015	0.351	0.079	0.089	0.173	
081991	0.760	-----	0.000?	0.000?	0.000	-----	
082691	-----	0.009	0.079	0.076	0.072	0.076	

1985- 93
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Date	TP04 NSR (mg/l)	TP04 BC-8e (mg/l)	1991 TP04 BC-3Ce (mg/l)	TP04 BC-3Ne (mg/l)	TP04 BC-3Se (mg/l)	TP04[1] BC-3e Avg (mg/l)	D
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
mu[1]	0.710	0.012	0.215	0.078	0.080	0.124	5.23
sig[1]	0.071	0.004	0.192	0.002	0.012	0.068	
090391	0.730	-----	0.000?	0.000?	0.000?	-----	
090991	-----	0.006	0.069	0.079	0.134	0.094	
091691	0.860	-----	0.000?	0.000?	0.000?	-----	
092391	-----	0.010	0.079	0.079	0.092	0.083	
093091	0.468	-----	0.000?	0.000?	0.000?	-----	
mu[1]	0.686	0.008	0.074	0.079	0.113	0.088	7.47
sig[1]	0.200	0.003	0.007	0.000	0.030	0.008	

? A real value or a space marker?

1 Zero values are not considered.

Table 1.2: The TPO4 (total phosphorus) data summarized in this table derive from the raw data provided by the City of Las Vegas and the Clark County Sanitation District for 1992. In this table, the cross sectional average values of the concentration of TPO4 at Station BC-3 (LVM-3) are computed and used to estimate dilution ratio coefficients.

Date (1)	TPO4 NSR (mg/l) (2)	TPO4 BC-8e (mg/l) (3)	1992 TPO4 BC-3Ce (mg/l) (4)	TPO4 BC-3Ne (mg/l) (5)	TPO4 BC-3Se (mg/l) (6)	TPO4 BC-3e Avg (mg/l) (7)	D (8)
040692	-----	0.005	0.021	0.024	0.024	0.023	
041392	0.730	-----	-----	-----	-----	-----	
042092	-----	0.012	0.058	0.049	0.116	0.074	
042792	0.570	-----	-----	-----	-----	-----	
mu	0.650	0.008	0.040	0.036	0.070	0.048	15.0
sig	0.113	0.005	0.026	0.018	0.065	0.036	
050492	-----	0.012	0.155	0.161	0.130	0.149	
051192	0.470	-----	-----	-----	-----	-----	
051892	-----	-----	0.095	0.089	0.088	0.091	
052692	-----	-----	0.042	0.033	0.041	0.039	
052792	1.160	-----	-----	-----	-----	-----	
mu	0.815	0.012	0.097	0.094	0.086	0.093	8.91
sig	0.487	0.000	0.057	0.064	0.045	0.055	
060192	-----	0.007	0.201	0.068	0.075	0.115	
060892	0.330	-----	-----	-----	-----	-----	
061592	-----	0.016	0.046	0.054	0.050	0.050	
062292	0.440	-----	-----	-----	-----	-----	
mu	0.385	0.012	0.124	0.061	0.062	0.082	4.33
sig	0.078	0.006	0.110	0.010	0.018	0.046	
070692	0.430	-----	-----	-----	-----	-----	
071392	-----	0.012	0.084	0.083	0.091	0.086	
072092	0.550	-----	-----	-----	-----	-----	
072792	-----	0.014	0.157	0.131	0.197	0.162	
mu	0.490	0.013	0.120	0.107	0.144	0.124	3.30
sig	0.085	0.001	0.052	0.034	0.075	0.054	
080492	-----	0.002	0.062	0.061	0.071	0.065	
081092	0.450	-----	-----	-----	-----	-----	
081792	-----	0.034	0.076	0.067	0.077	0.073	
082492	0.370	-----	-----	-----	-----	-----	
083192	-----	0.011	0.058	0.054	0.057	0.056	
mu	0.410	0.016	0.065	0.061	0.068	0.065	7.04
sig	0.057	0.017	0.009	0.007	0.010	0.009	
090892	0.440	-----	-----	-----	-----	-----	

1992

Date	TPO4 NSR (mg/l)	TPO4 BC-8e (mg/l)	TPO4 BC-3Ce (mg/l)	TPO4 BC-3Ne (mg/l)	TPO4 BC-3Se (mg/l)	TPO4 BC-3e Avg (mg/l)	D
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
091492	-----	0.008	0.058	0.061	0.059	0.059	
092892	-----	0.011	0.048	0.052	0.047	0.049	
mu	0.440	0.010	0.053	0.056	0.053	0.054	8.77
sig	0.000	0.002	0.007	0.006	0.008	0.007	

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Table 1.3: The TPO4 (total phosphorus) data summarized in this table derive from the raw data provided by the City of Las Vegas and the Clark County Sanitation District for 1993. In this table, the cross sectional average values of the concentration of TPO4 at Station BC-3 (LVM-3) are computed and used to estimate dilution ratio coefficients.

1993

Date (1)	TPO4 NSR (mg/l) (2)	TPO4 BC-8e (mg/l) (3)	TPO4 BC-3Ce (mg/l) (4)	TPO4 BC-3Ne (mg/l) (5)	TPO4 BC-3Se (mg/l) (6)	TPO4 BC-3e Avg (mg/l) (7)	D (8)
040593	0.380	-----	-----	-----	-----	-----	
041293	-----	0.010	0.090	0.090	0.100	0.093	
041993	0.350	-----	-----	-----	-----	-----	
042693	-----	0.030	0.060	0.050	0.100	0.070	
mu	0.365	0.020	0.075	0.070	0.100	0.082	4.56
sig	0.021	0.014	0.021	0.028	0.000	0.016	
050393	-----	0.010	0.070	-----	0.090	0.080	
051093	0.270	-----	-----	-----	-----	-----	
051793	-----	-----	0.050	0.050	0.060	0.053	
052493	-----	-----	-----	-----	-----	-----	
053193	-----	-----	0.070	0.070	0.080	0.073	
mu	0.270	0.010	0.063	0.060	0.077	0.069	3.41
sig	-----	-----	0.012	0.014	0.015	0.014	
060793	0.450	-----	-----	-----	-----	-----	
061593	-----	0.010	0.050	0.060	0.070	0.060	
062193	-----	0.010	0.040	0.050	0.070	0.053	
062893	0.480	-----	-----	-----	-----	-----	
mu	0.465	0.010	0.045	0.055	0.070	0.056	8.89
sig	0.021	0.000	0.007	0.007	0.000	0.005	
070693	-----	0.008	-----	-----	-----	-----	
070793	-----	-----	0.155	0.225	0.173	0.184	
071993	-----	0.011	0.085	0.073	0.103	0.087	
mu	-----	0.010	0.120	0.149	0.138	0.136	----
sig	-----	0.002	0.049	0.107	0.049	0.069	
080293	-----	0.011	0.085	0.079	0.098	0.087	
080993	-----	-----	-----	-----	-----	-----	
081693	-----	0.009	0.063	0.052	0.064	0.060	
082393	-----	-----	-----	-----	-----	-----	
083093	-----	0.010	0.098	0.081	0.078	0.086	
mu	-----	0.010	0.082	0.071	0.080	0.078	----
sig	-----	0.001	0.018	0.016	0.017	0.015	
090693	0.530	-----	-----	-----	-----	-----	
091393	-----	0.012	0.044	0.057	0.054	0.052	

Date	TPO4 NSR (mg/l)	TPO4 BC-8e (mg/l)	1993 TPO4 BC-3Ce (mg/l)	TPO4 BC-3Ne (mg/l)	TPO4 BC-3Se (mg/l)	TPO4 BC-3e Avg (mg/l)	D
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
092093	3.460	-----	-----	-----	-----	-----	
092793	-----	0.007	0.030	0.032	0.028	0.030	
mu	1.995	0.010	0.037	0.044	0.041	0.041	63.0
sig	2.072	0.004	0.010	0.018	0.018	0.016	

Table 1.4: The TPO4 (total phosphorus) data summarized in this table derive from French (1988), Table 5.1.

	1985				1986				1987			
Month	TPO4 NSR (mg/l)	TPO4 BC-8 (mg/l)	TPO4 BC-3 (mg/l)	D	TPO4 NSR (mg/l)	TPO4 BC-8 (mg/l)	TPO4 BC-3 (mg/l)	D	TPO4 NSR (mg/l)	TPO4 BC-8 (mg/l)	TPO4 BC-3 (mg/l)	D
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
4	0.820	0.020	0.047	29.6	0.753[3]	0.012	0.032	36.0	0.680	0.009	0.062	11.7
5	0.900	0.017	0.064	17.8	0.848	0.010	0.069	13.2	1.43	0.008	0.069	22.3
6	1.04	0.024	0.110	10.8	1.34	0.008	0.062	23.7	0.830[4]	0.008	0.052	17.7
7	1.34[1]	0.007	0.068	20.9	0.748	0.007	0.088	8.14	0.873[5]	0.008	0.082	10.7
8	0.797[2]	0.006	0.052	16.2	0.802	0.009	0.104	7.35	0.784	0.008	0.091	8.35
9	0.986	0.006	0.037	30.6	0.868	0.006	0.043	22.3	0.793	0.009	0.068	12.3
mu				21.0				18.4				13.8
sig				7.79				11.0				5.17

1 Data on 7/22/85 ignored because of unusually high flow.

2 data on 8/5/85 ignored because of unusually high flow.

3 Data on 4/7/86 ignored because of unusually high flow.

4 Data on 6/8/87 ignored because of unusually high flow.

5 Data on 7/27/87 ignored because of unusually high flow.

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APPENDIX 2

Table 2.1: The TNH (total ammonia) data summarized in this table derive from the raw data for the relevant months provided by the City of Las Vegas and the Clark County Sanitation District for 1991. In this table, the cross sectional average values of the concentration of TNH at Station BC-2 (LVM-2) are computed and used to estimate the dilution coefficient. Note: 1) the number of significant figures are those reported and 2) all concentrations reported as less than 0.40 mg/l were taken as 0.20 mg/l by a convention agreed to by all parties and these concentrations are indicated by an asterisk (*).

Date (1)	TNH NSR (mg/l) (2)	TNH BC-8e (mg/l) (3)	1991 TNH BC-2Ce (mg/l) (4)	TNH BC-2Ne (mg/l) (5)	TNH BC-2Se (mg/l) (6)	TNH BC-2e Avg (mg/l) (7)	D (8)
040291	12.470	-----	3.449	2.492	2.505	2.815	
040891	-----	0.200*	6.412	6.346	6.100	6.286	
041591	10.870	-----	2.623	2.460	4.500	3.194	
042291	-----	0.200*	0.200*	0.200*	0.408	0.269	
042991	9.659	-----	0.743	0.755	0.724	0.741	
mu	11.000	0.200	2.685	2.451	2.847	2.661	3.39
sig	1.410	0.000	2.471	2.404	2.444	2.390	
050791	-----	0.200*	2.120	1.963	4.005	2.696	
051391	11.300	-----	2.127	2.014	2.299	2.147	
052091	-----	0.811	1.348	1.316	6.090	2.918	
052891	12.500	-----	1.635	1.661	1.626	1.641	
mu	11.900	0.506	1.808	1.738	3.505	2.350	5.18
sig	0.849	0.432	0.383	0.322	1.993	0.573	
060391	-----	0.200*	2.117	2.061	1.817	1.998	
061091	-----	-----	2.791	2.819	2.910	2.840	
061191	1.067	-----	-----	-----	-----	-----	
062491	16.730	-----	2.010	2.131	2.189	2.110	
mu	8.898	0.200	2.306	2.337	2.305	2.316	3.11
sig	11.075	0.000	0.423	0.419	0.556	0.457	
070191	-----	0.953	1.579	1.492	4.641	2.571	
070891	11.219	-----	0.200*	0.405	0.451	0.352	
071591	-----	0.200*	1.839	1.581	1.920	1.780	
072291	10.697	-----	0.200*	0.465	0.407	0.357	
073091	-----	0.200*	-----	-----	-----	-----	
mu	10.958	0.451	0.954	0.986	1.855	1.265	11.9
sig	0.369	0.435	0.878	0.637	1.986	1.100	
080591	11.285	-----	0.589	0.566	0.648	0.601	
081291	-----	0.200*	0.200*	0.200*	0.200*	0.200	
082691	-----	-----	0.623	-----	0.579	0.601	
mu	11.285	0.200	0.471	0.383	0.476	0.467	40.5
sig	0.000	0.000	0.235	0.259	0.241	0.232	

Date	TNH NSR (mg/l)	TNH BC-8e (mg/l)	1991 TNH BC-2Ce (mg/l)	TNH BC-2Ne (mg/l)	TNH BC-2Se (mg/l)	TNH BC-2e Avg (mg/l)	D
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
090991	-----	0.200*	0.563	-----	-----	0.563	
091691	10.924	-----	0.511	0.531	0.475	0.506	
092391	-----	0.200*	0.937	0.833	0.869	0.880	
093091	13.130	-----	0.575	0.587	0.577	0.580	
mu	12.027	0.200	0.646	0.650	0.640	0.632	26.4
sig	1.560	0.000	0.196	0.161	0.204	0.168	

Table 2.2: The TNH (total ammonia) data summarized in this table derive from the raw data provided by the City of Las Vegas and the Clark County Sanitation District for 1992. In this table, the cross sectional average values of the concentration of TNH at Station BC-2 (LVM-2) are computed and used to estimate the dilution coefficient. Note: 1) the number of significant figures are those reported and 2) all concentrations reported as less than 0.40 mg/l were taken as 0.20 mg/l by a convention agreed to by all parties and these concentrations are indicated by an asterisk (*).

Date (1)	TNH NSR (mg/l) (2)	TNH BC-8e (mg/l) (3)	1992 TNH BC-2Ce (mg/l) (4)	TNH BC-2Ne (mg/l) (5)	TNH BC-2Se (mg/l) (6)	TNH BC-2e Avg (mg/l) (7)	D (8)
040692	----	0.20*	0.20*	0.20*	0.20*	0.20	
041392	8.63	----	----	----	----	----	
041492	----	----	0.20*	0.43	0.46	0.36	
042092	----	0.20*	1.05	1.19	0.78	1.01	
042792	10.74	----	----	----	----	----	
042892	----	----	2.22	2.57	2.32	2.37	
mu	9.68	0.20	0.92	1.10	0.94	0.98	11.2
sig	1.49	0.00	0.96	1.07	0.95	0.99	
050492	-----	0.20*	0.91	1.68	1.72	1.44	
051192	10.90	----	----	----	----	----	
051292	-----	----	0.47	0.20*	0.40	0.36	
052692	-----	----	0.73	0.20*	0.44	0.46	
052792	4.98	----	----	----	----	----	
mu	7.94	0.20	0.70	0.69	0.85	0.75	13.1
sig	4.19	0.00	0.22	0.85	0.75	0.60	
060192	-----	----	1.98	1.75	1.90	1.88	
060892	10.91	----	----	----	----	----	
060992	-----	----	0.20*	0.20*	0.20*	0.20	
061592	-----	0.20*	0.20*	0.20*	0.20*	0.20	
062292	7.56	----	----	----	----	----	
062392	-----	----	0.20*	0.20*	0.20*	0.20	
mu	9.24	0.20	0.64	0.59	0.62	0.62	20.5
sig	2.37	0.00	0.89	0.78	0.85	0.84	
070692	8.42	----	----	----	----	----	
070792	----	----	0.20*	0.20*	0.20*	0.20	
071392	-----	0.20*	0.20*	0.20*	0.20*	0.20	
072092	7.31	----	----	----	----	----	
072192	----	----	0.74	0.74	0.58	0.69	
072792	----	0.20*	0.20*	0.20*	0.20*	0.20	
mu	7.86	0.20	0.34	0.34	0.30	0.32	62.8
sig	0.78	0.00	0.27	0.27	0.19	0.24	
080492	----	0.20*	0.20*	0.20*	0.20*	0.20	
081092	2.08	----	----	----	----	----	
081192	----	----	0.20*	0.20*	0.20*	0.20	

Date (1)	TNH NSR (mg/l) (2)	TNH BC-8e (mg/l) (3)	1992 TNH BC-2Ce (mg/l) (4)	TNH BC-2Ne (mg/l) (5)	TNH BC-2Se (mg/l) (6)	TNH BC-2e Avg (mg/l) (7)	D (8)
081792	----	0.20*	0.40	0.20*	0.50	0.37	
082492	6.53	----	----	----	----	----	
082592	----	----	0.20*	0.20*	0.20*	0.20	
083192	----	0.20*	0.20*	----	0.20*	0.20	
mu	4.30	0.20	0.24	0.20	0.26	0.23	136.
sig	3.15	0.00	0.09	0.00	0.13	0.08	
090892	6.91	----	----	----	----	----	
090892	----	----	0.20*	0.20*	0.20*	0.20	
091492	----	0.20*	0.67	0.20*	0.20*	0.36	
092892	----	0.20*	0.42	0.20*	0.58	0.40	
mu	6.91	0.20	0.43	0.20	0.33	0.32	54.9
sig	0.00	0.00	0.24	0.00	0.22	0.11	

Table 2.3: The TNH (total ammonia) data summarized in this table derive from the raw data provided by the City of Las Vegas and the Clark County Sanitation District for 1993. In this table, the cross sectional average values of the concentration of TNH at Station BC-2 (LVM-2) are computed and used to estimate the dilution coefficient. Note: 1) the number of significant figures are those reported and 2) all concentrations reported as less than 0.40 mg/l were taken as 0.20 mg/l by a convention agreed to by all parties and these concentrations are indicated by an asterisk (*).

			1993				
Date	TNH NSR (mg/l)	TNH BC-8e (mg/l)	TNH BC-2Ce (mg/l)	TNH BC-2Ne (mg/l)	TNH BC-2Se (mg/l)	TNH BC-2e Avg (mg/l)	D
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
040593	8.91	----	----	----	----	----	
040693	----	----	0.20*	0.20*	0.20*	0.20	
041293	----	0.20*	4.19	1.43	4.35	3.32	
041993	2.31	----	----	----	----	----	
042093	----	----	0.20*	0.20*	0.20*	0.20	
042693	----	0.20*	0.20*	0.20*	0.20*	0.20	
mu	5.61	0.20	1.20	0.51	1.24	0.98	5.94
sig	4.67	0.00	2.00	0.62	2.08	1.56	
050393	----	0.20*	0.20*	----	0.20*	0.20	
051093	2.88	----	----	----	----	----	
051192	----	----	0.78	0.54	0.78	0.70	
051792	----	0.20*	0.20*	0.20*	3.89	1.43	
052493	9.57	----	----	----	----	----	
053193	----	0.20*	0.20*	0.74	0.20*	0.38	
mu	6.22	0.20	0.34	0.49	1.27	0.68	11.5
sig	4.73	0.00	0.29	0.27	1.77	0.54	
060793	13.78	----	0.78	0.83	0.20*	0.60	
061593	-----	0.20*	0.20*	0.20*	0.20*	0.20	
062193	-----	0.20*	0.20*	0.20*	0.20*	0.20	
062893	8.23	----	----	----	----	----	
062993	-----	----	0.20*	0.20*	0.20*	0.20	
mu	11.00	0.20	0.34	0.36	0.20	0.30	107.
sig	3.92	0.00	0.29	0.32	0.00	0.20	
070693	----	0.20*	----	----	----	----	
070793	----	----	0.20*	0.20*	0.20*	0.20	
071293	5.70	----	----	----	----	----	
071393	----	----	0.20*	0.20*	0.20*	0.20	
071993	----	0.20*	0.20*	0.20*	0.20*	0.20	
072893	----	----	----	----	2.54	2.54	
mu	5.70	0.20	0.20	0.20	0.78	0.78	8.48
sig	0.00	0.00	0.00	0.00	1.17	1.17	
080293	----	0.20*	3.31	0.20*	0.20*	1.24	

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Date	TNH NSR (mg/l)	TNH BC-8e (mg/l)	1993 TNH BC-2Ce (mg/l)	TNH BC-2Ne (mg/l)	TNH BC-2Se (mg/l)	TNH BC-2e Avg (mg/l)	D
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
080993	12.51	----	0.20*	0.20*	0.20*	0.20	
081693	----	0.20*	0.20*	0.20*	0.20*	0.20	
082393	10.77	----	0.20*	0.20*	0.20*	0.20	
083093	----	0.20*	0.20*	0.20*	0.20*	0.20	
mu	11.64	0.20	0.82	0.20	0.20	0.41	53.5
sig	1.23	0.00	1.39	0.00	0.00	0.47	
090693	7.68	----	----	----	----	----	
091393	----	0.20*	0.20*	0.20*	0.20*	0.20	
092093	1.66	----	0.20*	0.20*	0.20*	0.20	
092793	----	0.20*	0.20*	0.20*	0.20*	0.20	
mu	4.67	0.20	0.20	0.20	0.20	0.20	Indeterminate
sig	4.26	0.00	0.00	0.00	0.20	0.00	Value

APPENDIX 3

Table 3.1: The pH data summarized in this table derive from the raw data for the relevant months provided by the City of Las Vegas and the Clark County Sanitation District for 1991. In this table, the cross-sectional values of pH at Station BC-2 (LVM-2) are computed for subsequent use.

Date (1)	pH NSR (2)	pH BC-8e (3)	1991 pH BC-2Ce (4)	pH BC-2Ne (5)	pH BC-2Se (6)	pH BC-2 Geo. Mean (7)
040291	8.00	----	7.61	7.61	7.62	7.61
040891	----	7.84	7.61	7.54	7.63	7.59
041591	8.23	----	8.20	8.18	8.15	8.17
042291	----	7.99	8.24	8.26	8.19	8.23
042991	7.37	----	8.20	8.18	8.24	8.20
Geo. Mean	7.70	7.91	7.97	7.95	7.96	7.95
050791	----	????	8.23	8.21	8.22	8.22
051391	7.43	----	8.25	8.31	8.20	8.25
052091	----	8.22	8.09	8.09	7.83	8.00
052891	7.85	----	8.19	8.20	8.17	8.18
Geo. Mean	7.64	8.22	8.19	8.20	8.10	8.16
060391	----	8.09	7.96	7.98	7.98	7.97
061091	----	----	8.28	8.34	8.24	8.28
061191	7.77	----	----	----	----	----
061791	----	8.33	8.29	8.29	8.29	8.29
062491	7.67	----	8.42	8.43	8.40	8.41
Geo. Mean	7.72	8.21	8.24	8.26	8.23	8.24
070191	----	8.50	8.58	8.55	8.23	8.45
070891	7.87	----	8.75	8.74	8.78	8.76
071591	----	8.54	8.41	8.38	8.41	8.40
072291	7.62	----	8.59	8.46	8.52	8.52
073091	----	8.28	----	----	----	----
Geo. Mean	7.74	8.26	8.58	8.53	8.48	8.53
080591	7.96	----	8.05	8.05	7.91	8.00
081291	----	8.60	9.09	9.09	9.09	9.09
081991	7.68	----	8.85	8.84	8.84	8.84
082691	----	8.41	8.79	8.72	8.76	8.75
Geo. Mean	7.82	8.50	8.69	8.67	8.64	8.66
090391	7.29	----	8.21	8.30	8.16	8.22
090991	----	8.04	8.11	----	----	8.11
091691	7.48	----	8.56	8.59	8.60	8.58
092391	----	8.60	8.44	8.46	8.37	8.42
093091	7.37	----	7.92	7.90	7.97	7.93
Geo. Mean	7.23	8.32	8.24	8.31	8.27	8.25

Table 3.2: The pH data summarized in this table derive from the raw data for the relevant months provided by the City of Las Vegas and the Clark County Sanitation District for 1992. In this table, the cross-sectional values of pH at Station BC-2 (LVM-2) are computed for subsequent use.

Date (1)	pH NSR (2)	pH BC-8e (3)	1992 pH BC-2Ce (4)	pH BC-2Ne (5)	pH BC-2Se (6)	pH BC-2 Geo. Mean (7)
040692	----	8.18	8.25	8.24	8.27	8.25
041392	7.62	----	----	----	----	----
041492	----	----	8.55	8.56	8.65	8.58
042092	----	8.33	8.42	8.44	8.46	8.44
042792	7.60	----	----	----	----	----
042892	----	----	8.32	8.26	8.44	8.34
Geo. Mean	7.61	8.25	8.38	8.37	8.45	8.40
050492	----	8.36	8.71	8.79	8.80	8.76
051192	7.47	----	----	----	----	----
051292	----	----	8.37	8.35	8.36	8.36
051892	----	----	8.32	8.29	8.34	8.31
052692	----	----	8.35	8.35	8.32	8.34
052792	7.47	----	----	----	----	----
Geo. Mean	7.47	8.36	8.44	8.44	8.45	8.44
060192	----	8.32	8.54	8.59	8.67	8.60
060892	7.51	----	----	----	----	----
060992	----	----	8.53	8.48	8.58	8.53
061592	----	8.32	8.22	8.27	8.25	8.24
062292	7.53	----	----	----	----	----
062392	----	----	8.50	8.50	8.56	8.52
Geo. Mean	7.52	8.32	8.45	8.46	8.51	8.47
070692	7.72	----	----	----	----	----
070792	----	----	8.44	8.41	8.33	8.39
071392	----	8.34	8.75	9.01	9.03	8.93
072092	7.54	----	----	----	----	----
072192	----	----	8.68	8.63	8.70	8.67
072792	----	8.28	8.73	8.86	8.83	8.80
Geo. Mean	7.63	8.31	8.65	8.72	8.72	8.70
080492	----	8.25	8.46	8.42	8.52	8.46
081092	7.60	----	----	----	----	----
081192	----	----	8.30	8.20	8.30	8.26
081792	----	8.36	8.80	8.86	8.92	8.86
082492	7.42	----	----	----	----	----
082592	----	----	8.39	8.40	8.41	8.40
083192	----	8.29	8.59	8.45	8.61	8.55
Geo. Mean	7.51	8.13	8.51	8.46	8.55	8.50
090892	7.63	----	8.42	8.36	8.48	8.42
091492	----	8.28	8.70	8.74	8.67	8.70
092192	7.44	----	----	----	----	----

Date	pH NSR	pH BC-8e	1992 pH BC-2Ce	pH BC-2Ne	pH BC-2Se	pH BC-2 Geo. Mean
(1)	(2)	(3)	(4)	(5)	(6)	(7)
092292	----	----	8.35	8.31	8.41	8.35
092892	----	8.25	8.52	8.54	8.44	8.50
Geo. Mean	7.53	8.26	8.50	8.49	8.50	8.49

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Table 3.3: The pH data summarized in this table derive from the raw data for the relevant months provided by the City of Las Vegas and the Clark County Sanitation District for 1993. In this table, the cross-sectional values of pH at Station BC-2 (LVM-2) are computed for subsequent use.

1993

Date (1)	pH NSR (2)	pH BC-8e (3)	pH BC-2Ce (4)	pH BC-2Ne (5)	pH BC-2Se (6)	pH BC-2 Geo. Mean (7)
040593	7.28	----	----	----	----	----
040693	----	----	8.38	8.30	8.33	8.33
041293	----	7.90	7.77	7.86	7.91	7.84
041993	7.09	----	----	----	----	----
042093	----	----	8.30	8.26	8.27	8.27
042693	----	8.05	8.49	8.45	8.65	8.53
Geo. Mean	7.18	7.97	8.23	8.21	8.29	8.24
050393	----	8.12	8.50	----	8.59	8.54
051093	7.25	----	----	----	----	----
051193	----	----	8.40	8.39	8.42	8.40
051793	----	----	8.46	8.45	8.46	8.45
052493	7.36	----	----	----	----	----
053193	----	8.15	8.31	8.36	8.32	8.33
Geo. Mean	7.30	8.13	8.42	8.22	8.45	8.43
060793	7.39	----	8.26	8.21	8.23	8.23
061593	----	8.22	8.66	8.92	8.65	8.74
062193	----	8.25	8.59	8.76	8.71	8.68
062893	7.58	----	----	----	----	----
062993	----	----	8.42	8.38	8.43	8.41
Geo. Mean	7.48	8.23	8.48	8.56	8.50	8.51
070693	----	8.38	----	----	----	----
070793	----	----	8.88	8.70	8.80	8.79
071293	7.62	----	----	----	----	----
071393	----	----	8.54	8.54	8.64	8.57
071993	----	8.31	8.84	8.89	8.86	8.86
072893	----	----	8.19	8.14	8.21	8.18
Geo. Mean	7.62	8.34	8.61	8.56	8.62	8.60
080293	----	8.30	8.51	8.36	8.59	8.48
080993	7.46	----	8.58	8.44	8.61	8.54
081693	----	8.37	8.58	8.62	8.66	8.62
082393	7.34	----	8.48	8.55	8.51	8.51
083093	----	8.17	8.63	8.58	8.68	8.63
Geo. Mean	7.40	8.11	8.56	8.51	8.61	8.56
090693	7.37	----	----	----	----	----
091393	----	8.15	8.30	8.31	8.32	8.31

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Date	pH	pH	1993 pH	pH	pH	pH
	NSR	BC-8e	BC-2Ce	BC-2Ne	BC-2Se	BC-2 Geo. Mean
(1)	(2)	(3)	(4)	(5)	(6)	(7)
092093	7.26	----	8.00	7.96	8.03	7.99
092793	----	8.15	8.24	8.24	8.24	8.24
Geo. Mean	7.31	8.15	8.01	8.00	8.03	8.18

Table 3.4: The temperature data summarized in this table derive from the raw data for the relevant months provided by the City of Las Vegas and the Clark County Sanitation District for 1991. In this table, the cross sectional average values of the temperature at Station BC-2 (LVM-2) are computed for subsequent use.

1991

Date (1)	T NSR (°C) (2)	T BC-8e (°C) (3)	T BC-2Ce (°C) (4)	T BC-2Ne (°C) (5)	T BC-2Se (°C) (6)	T BC-2e Avg (°C) (7)	T BC-2e Sig (°C) (8)
040291	21.70	-----	15.10	15.20	15.10	15.13	0.058
040891	-----	13.00	18.00	17.70	17.90	17.87	0.153
041591	22.00	-----	16.20	16.20	16.50	16.30	0.173
042291	-----	15.20	17.70	17.80	18.00	17.83	0.153
042991	21.80	-----	16.20	16.20	16.30	16.23	0.058
mu	21.83	14.10	16.64	16.62	16.76	16.67	-----
sig	0.153	1.556	1.197	1.110	1.212	1.171	-----
050791	-----	17.90	20.50	20.40	20.30	20.40	0.100
051391	24.10	-----	18.90	19.00	19.00	18.97	0.058
052091	-----	17.90	19.30	19.30	20.80	19.80	0.866
052891	24.30	-----	21.50	21.50	21.60	21.53	0.058
mu	24.20	17.90	20.05	20.05	20.42	20.18	-----
sig	0.141	0.000	1.182	1.139	1.090	1.077	-----
060391	-----	20.30	23.40	23.30	23.70	23.47	0.208
061091	-----	-----	25.40	25.40	24.90	25.23	0.289
061191	26.80	-----	-----	-----	-----	-----	-----
061791	-----	20.80	25.40	25.40	25.40	25.40	0.000
062491	27.10	-----	24.70	24.70	24.70	24.70	0.000
mu	26.95	20.55	24.72	24.70	24.68	24.70	-----
sig	0.212	0.354	0.943	0.990	0.714	0.873	-----
070191	-----	23.70	26.30	26.20	27.10	26.53	0.493
070891	28.30	-----	27.70	27.80	27.60	27.70	0.100
071591	-----	26.60	27.30	27.30	27.40	27.33	0.058
072291	29.00	-----	27.80	27.40	27.70	27.63	0.208
073091	-----	27.50	-----	-----	-----	-----	-----
mu	28.65	25.93	27.28	27.18	27.45	27.30	-----
sig	0.495	1.986	0.685	0.685	0.265	0.536	-----
080591	29.00	-----	28.60	28.80	28.70	28.70	0.100
081291	-----	26.70	28.80	28.90	28.70	28.80	0.100
081991	29.50	-----	29.70	29.60	29.70	29.67	0.058
082691	-----	27.30	29.80	30.30	30.10	30.07	0.252
mu	29.25	27.00	29.22	29.65	29.30	29.31	-----
sig	0.354	0.424	0.613	0.580	0.712	0.668	-----

1991

Date (1)	T NSR (°C) (2)	T BC-8e (°C) (3)	T BC-2Ce (°C) (4)	T BC-2Ne (°C) (5)	T BC-2Se (°C) (6)	T BC-2e Avg (°C) (7)	T BC-2e Sig (°C) (8)
090391	28.70	-----	28.40	28.40	28.30	28.37	0.058
090991	-----	26.60	27.70	-----	-----	27.70	-----
091691	26.10	-----	26.10	26.00	26.10	26.07	0.058
092391	-----	25.00	27.00	26.90	26.90	26.93	0.058
093091	27.70	-----	25.50	25.50	25.60	25.53	0.058
mu	27.50	25.80	26.94	26.70	26.72	26.92	-----
sig	1.311	1.131	1.172	1.273	1.179	1.158	-----

Table 3.5: The temperature data summarized in this table derive from the raw data for the relevant months provided by the City of Las Vegas and the Clark County Sanitation District for 1992. In this table, the cross sectional average values of the temperature at Station BC-2 (LVM-2) are computed for subsequent use.

Date	T NSR (^{o}C)	T BC-8e (^{o}C)	1992 T BC-2Ce (^{o}C)	T BC-2Ne (^{o}C)	T BC-2Se (^{o}C)	T BC-2e Avg (^{o}C)	T BC-2e Sig (^{o}C)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
040692	----	15.6	19.0	18.8	19.1	19.0	0.15
041392	19.2	----	----	----	----	----	----
041492	----	----	21.1	21.1	21.4	21.2	0.17
042092	----	17.7	20.4	20.1	20.4	20.3	0.17
042792	22.2	----	----	----	----	----	----
042892	----	----	22.6	22.7	22.8	22.7	0.10
mu	20.7	16.6	20.8	20.7	20.9	20.8	----
sig	2.12	1.48	1.50	1.65	1.56	1.55	----
050492	----	21.4	24.9	24.9	24.4	24.7	0.29
051192	23.6	----	----	----	----	----	----
051292	----	----	23.9	24.0	24.0	24.0	0.06
051892	----	----	24.7	24.7	24.7	24.7	0.00
052692	----	----	25.1	25.0	25.1	25.1	0.06
052792	23.8	----	----	----	----	----	----
mu	23.7	21.4	24.6	24.6	24.6	24.6	----
sig	0.14	----	0.52	0.45	0.47	0.56	----
060192	----	24.0	27.7	27.2	27.6	27.5	0.26
060892	24.2	----	----	----	----	----	----
060992	----	----	25.9	25.8	25.9	25.9	0.06
061592	----	22.8	23.6	23.5	23.6	23.6	0.06
062292	24.3	----	----	----	----	----	----
062392	-----	----	25.9	25.8	26.0	25.9	0.10
mu	24.2	23.4	25.8	25.6	25.8	25.7	----
sig	0.212	0.354	0.943	0.990	0.714	1.60	----
070692	26.0	----	----	----	----	----	----
070792	-----	----	25.6	25.6	25.6	25.6	0.00
071392	----	25.1	28.1	27.9	28.0	28.0	0.10
072092	26.4	----	----	----	----	----	----
072192	----	----	29.0	28.9	29.0	29.0	0.06
072792	----	26.6	30.4	30.5	30.6	30.5	0.10
mu	26.2	25.8	28.3	28.2	28.3	28.3	----
sig	0.28	1.06	2.02	2.05	2.09	2.06	----
080492	----	26.8	29.5	29.4	29.4	29.4	0.06
081092	25.3	----	----	----	----	----	----
081192	-----	----	29.6	29.3	29.7	29.5	0.21
081792	----	29.5	31.7	31.6	31.9	31.7	0.15

Date (1)	T NSR (°C) (2)	T BC-8e (°C) (3)	1992 T BC-2Ce (°C) (4)	T BC-2Ne (°C) (5)	T BC-2Se (°C) (6)	T BC-2e Avg (°C) (7)	T BC-2e Sig (°C) (8)
082492	24.0	----	----	----	----	----	----
082592	----	----	28.5	28.6	28.6	28.6	0.06
083192	----	26.2	28.1	28.1	28.0	28.1	0.06
mu	24.6	27.5	29.5	29.4	29.5	29.5	----
sig	0.92	1.76	1.40	1.34	1.49	1.38	----
090892	27.9	----	26.8	26.7	27.0	26.8	0.15
091492	----	25.8	27.5	27.5	27.4	27.5	0.06
092192	23.6	----	----	----	----	----	----
092292	----	----	26.8	26.7	26.8	26.8	0.06
092892	----	25.7	26.2	26.3	26.1	26.2	0.10
mu	25.8	25.8	26.8	26.8	26.8	26.8	----
sig	3.04	0.07	0.53	0.50	0.54	0.53	----

Table 3.6: The temperature data summarized in this table derive from the raw data for the relevant months provided by the City of Las Vegas and the Clark County Sanitation District for 1993. In this table, the cross sectional average values of the temperature at Station BC-2 (LVM-2) are computed for subsequent use.

Date (1)	T NSR (°C) (2)	T BC-8e (°C) (3)	1993 T BC-2Ce (°C) (4)	T BC-2Ne (°C) (5)	T BC-2Se (°C) (6)	T BC-2e Avg (°C) (7)	T BC-2e Sig (°C) (8)
040593	18.20	-----	-----	-----	-----	-----	-----
040693	-----	-----	16.70	16.70	16.80	16.73	0.058
041293	-----	15.80	18.70	18.50	19.00	18.73	0.252
041993	17.30	-----	-----	-----	-----	-----	-----
042093	-----	-----	17.70	17.60	17.90	17.73	0.153
042693	-----	21.00	20.00	20.00	20.40	20.13	0.231
mu	17.75	18.40	18.28	18.20	18.52	18.33	-----
sig	0.636	3.677	1.410	1.407	1.539	1.451	-----
050393	-----	19.60	22.00	-----	22.00	22.00	0.000
051093	18.80	-----	-----	-----	-----	-----	-----
051193	-----	-----	20.88	20.67	21.16	20.90	0.246
051793	-----	-----	23.23	23.16	23.29	23.23	0.065
052493	22.79	-----	-----	-----	-----	-----	-----
053193	-----	22.62	24.36	24.88	24.37	24.54	0.297
mu	20.80	21.11	22.62	22.90	22.70	22.92	-----
sig	2.821	2.135	1.507	2.117	1.414	1.991	-----
060793	19.79	-----	22.39	22.33	22.46	22.39	0.065
061593	-----	23.64	27.63	27.47	27.50	27.53	0.085
062193	-----	25.13	26.30	26.43	26.47	26.40	0.089
062893	24.53	-----	-----	-----	-----	-----	-----
062993	-----	-----	24.66	24.51	24.66	24.61	0.087
mu	22.16	24.38	25.24	25.18	25.27	25.23	-----
sig	3.352	1.054	2.258	2.264	2.212	2.244	-----
070693	-----	24.10	-----	-----	-----	-----	-----
070793	-----	-----	27.28	27.15	27.39	27.27	0.120
071293	25.80	-----	-----	-----	-----	-----	-----
071393	-----	-----	27.46	27.37	27.49	27.44	0.062
071993	-----	24.59	27.24	27.25	27.86	27.45	0.355
072893	-----	-----	27.50	27.07	27.79	27.45	0.362
mu	25.80	24.34	27.37	27.21	27.63	27.40	-----
sig	-----	0.346	0.129	0.130	0.228	0.088	-----
080293	-----	27.27	29.02	28.89	29.21	29.04	0.161
080993	24.82	-----	28.48	28.58	28.59	28.55	0.061
081693	-----	25.81	27.61	28.43	27.63	27.89	0.468
082393	22.96	-----	27.71	27.64	27.70	27.68	0.038
083093	-----	26.06	28.43	28.33	28.50	28.42	0.085

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			1993				
Date	T NSR (°C)	T BC-8e (°C)	T BC-2Ce (°C)	T BC-2Ne (°C)	T BC-2Se (°C)	T BC-2e Avg (°C)	T BC-2e Sig (°C)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
mu	23.89	26.38	28.25	28.37	28.33	28.32	----
sig	1.315	0.781	0.587	0.462	0.663	0.542	----
090693	22.82	-----	-----	-----	-----	-----	-----
091393	-----	25.61	26.80	26.77	26.85	26.81	0.040
092093	20.07	-----	25.15	25.13	25.18	25.15	0.025
092793	-----	24.57	25.98	24.76	25.05	25.26	0.637
mu	21.44	25.09	25.98	25.55	25.69	25.74	-----
sig	1.944	0.735	0.825	1.069	0.992	0.928	-----

APPENDIX 4

```
c
c
c     This program is designed to perform a stochastic simulation
c     to use the water quality standard for total phosphorus at
c     station BC-3 on Lake Mead to estimate the allowable concentration
c     at NSR to meet this standard.
c
c     THIS VERSION OF THE PROGRAM WAS LAST MODIFIED ON 12/27/93
c
c
c     D = dilution ratio
c     sigd = standard deviation associated with D
c
      dimension cw(1000),cwbar(1000)
c     Input average value and standard deviation of D April thru Sept
c
c     These data are the average data for the period 1985-1987
c
      write(6,101)
 101  format(5x,'THIS PROGRAM USES AVERAGE DATA FROM THE PERIOD',/,
     c15x,'1985-1987 INCLUSIVE')
      dapr=25.8
      sdapr=12.6
      dmay=17.8
      sdmay=4.55
      djun=17.4
      sdjun=6.46
      djul=13.2
      sdjul=6.75
      daug=10.6
      sdaug=4.85
      dsep=21.7
      sdsep=9.16
c
c
c
c
c     Input average value and standard deviation of cb
c     for April thru September
c
c     These data are the average data for the period 1985-1987
c
      cbapr=0.011
      scapr=0.005
      cbmay=0.010
      scmay=0.004
      cbjun=0.010
      scjun=0.006
      cbjul=0.008
      scjul=0.002
      cbaug=0.008
      scaug=0.003
      cbsep=0.007
      scsep=0.002
c
c     cstand =  concentration of TPO4 at Station BC-3 to meet
c               the water quality standard
c
      print *
      print *,'Input target TPO4 concentration at Station BC-3 '
      read(5,*)cstand
      idum=-5
      print *
      print *,'Input the number of years to be simulated '
```

```
      read(5,*)nsim
      do 1 i=1,nsim
      call simu(idum,dapr,sdapr,cbapr,scapr,cstand,capr)
      call simu(idum,dmay,sdmay,cbmay,scmay,cstand,cmay)
      call simu(idum,djun,sdjun,cbjun,scjun,cstand,cjun)
      call simu(idum,djul,sdjul,cbjul,scjul,cstand,cjul)
      call simu(idum,daug,sdaug.cbaug,scaug,cstand,caug)
      call simu(idum,dsep,sdsep,cbsep,scsep,cstand,csep)
      cw(i)=(capr+cmay+cjun+cjul+caug+csep)/6.
      if(i .lt. 4)go to 1
      j=i-3
      cwbar(j)=(cw(i-3)+cw(i-2)+cw(i-1)+cw(i))/4.
 1    continue
      xn=nsim
      sum1=0.
      sum2=0.
      do 2 i=1,nsim-3
      sum1=sum1+cwbar(i)
      sum2=sum2+cwbar(i)**2
 2    continue
      cwavg=sum1/(xn-3.)
      cwsig=sqrt((sum2/(xn-3.))-cwavg**2)
      write(6,100)xn,cwavg,cwsig
 100  format(/,/,/,5x,'Number of simulations = ',f8.0,/,
     c5x,'Target 4-yr average po4 concentration at NSR = ',f8.2,
     c' mg/l',/,5x,'Standard deviation associated with 4-yr ',
     c'average value = ',f8.3,' mg/l')
      stop
      end
c
c
c
      subroutine simu(idum,d,sd,cb,scb,cstand,c)
 1    dran=d+sd*gasdev(idum)
      if(dran .le. 0.)go to 1
 2    cran=cb+scb*gasdev(idum)
      if(cran .le. 0.)go to 2
      c=(dran+1.)*cstand-dran*cran
      return
      end
c
c     Returns a normally distributed deviate with zero mean
c     and a unit variance using RAN1(IDUM)
c
c     From Numerical Recipes, Press, Flannery, Teukolsky,
c     and Vetterling, Cambridge University Press, pp. 200-203

c
c
      function gasdev(idum)
      data iset/0/
      if(iset .eq. 0)then
 1       v1=2.*ran1(idum)-1.
         v2=2.*ran1(idum)-1.
         r=v1**2+v2**2
         if(r .ge. 1)go to 1
         fac=sqrt(-2.*log(r)/r)
         gset=v1*fac
         gasdev=v2*fac
         iset=1
      else
         gasdev=gset
         iset=0
      endif
```

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```
      return
      end
c
c     Returns a uniform random deviate between 0.0 and 1.
c     Set IDUM to any negative value to initialize or
c     reinitialize the sequence.
c
c     From Numerical Recipes, Press, Flannery, Teukolsky,
c     and Vetterling, Cambridge University Press, pp. 196-197.
c
c
      function ran1(idum)
      dimension r(97)
      parameter (m1=259200,ia1=7141,ic1=54773,rm1=1./m1)
      parameter (m2=134456,ia2=8121,ic2=28411,rm2=1./m2)
      parameter (m3=243000,ia3=4561,ic3=51349)
      data iff /0/
      if(idum .lt. 0 .or. iff .eq. 0)then
         iff=1
         ix1=mod(ic1-idum,m1)
         ix1=mod(ia1*ix1+ic1,m1)
         ix2=mod(ix1,m2)
         ix1=mod(ia1*ix1+ic1,m1)
         ix3=mod(ix1,m3)
         do 11 j=1,97
            ix1=mod(ia1*ix1+ic1,m1)
            ix2=mod(ia2*ix2+ic2,m2)
            r(j)=(float(ix1)+float(ix2)*rm2)*rm1
 11      continue
         idum=1
      endif
      ix1=mod(ia1*ix1+ic1,m1)
      ix2=mod(ia2*ix2+ic2,m2)
      ix3=mod(ia3*ix3+ic3,m3)
      j=1+(97*ix3)/m3
      if(j .gt. 97 .or. j .lt. 1)pause
      ran1=r(j)
      r(j)=(float(ix1)+float(ix2)*rm2)*rm1
      return
      end
```

APPENDIX 5

```
c
c     This program is designed to perform a stochastic simulation
c     to use the water quality standard for un-ionized ammonia at
c     station BC-2 on Lake Mead to estimate the allowable concentration
c     at NSR to meet this standard.
c
c     THIS VERSION OF THE PROGRAM WAS LAST MODIFIED ON 3/5/94
c
      dimension f(190),n(6)
      write(6,101)
 101  format(5x,'THIS PROGRAM USES AVERAGE DATA FROM THE PERIOD',/,
     c15x,'1985-1993, EXCEPT THE PERIOD 1988-1990, INCLUSIVE',/,/)
      real mub,mufui,mud
      open(unit=2,status='scratch')
      open(unit=3,status='scratch')
      mud=28.2
      sigd=14.9
      mub=0.125
      sigb=0.025
      mufui=0.188
      sigfui=0.071
      n(1)=30
      n(2)=31
      n(3)=30
      n(4)=31
      n(5)=31
      n(6)=30
      print *,'Input number of critical periods to be simulated '
      read(5,*)nn
      do 2 j=1,nn
      do 3 i=1,6
      do 4 k=1,n(i)
44    dild=mud+xrand()*sigd
      if(dild .le. 0.)go to 44
5     cb=mub+xrand()*sigb
      if(cb .le. 0.)go to 5
6     fui=mufui+xrand()*sigfui
      if(fui .le. 0.)go to 6
      f1=((0.04/fui)*(dild+1.))-(dild*cb)
      if(f1 .lt. 0)go to 44
      write(2,*)f1
4     continue
3     continue
      rewind 2
      sum=0.
      do 7 i=1,183
      read(2,*)f(i)
      if(i .lt. 4)go to 7
      sum=(f(i)+f(i-1)+f(i-2)+f(i-3))/4.
      if(i .eq. 4)sumold=sum
      if(sum .lt. sumold)sumold=sum
7     continue
      rewind 2
      write(3,*)sumold
2     continue
      rewind 3
      sumx=0.
      sumx2=0.
      xn=0.
8     read(3,*,end=999)x
      xn=xn+1.
      sumx=sumx+x
      sumx2=sumx2+x**2
      go to 8
```

```
 999  avg=sumx/xn
      f1=(sumx2/xn)-avg**2
      s=sqrt(f1)
      write(6,100)xn,avg,s
 100  format(1x,'after ',f5.0,' iterations',/
     c,5x,'avg = ',f10.3,/,5x,'s = ',f10.6)
      stop
      end
c
c
c
c
      function xrand()
c
c
c     random number generator
c
c
c     source:  Ripley, B.D., 1987.  stochastic simulation, wiley
c              p. 82
c
c
 10   u=rnd()
      v=0.8578*(2.*rnd()-1.)
      x=v/u
      z=0.25 *x*x
      if(z .lt. (1.-u))go to 20
      if(z .gt. (0.259/u+0.35))go to 10
      if(z .gt. -alog(u))go to 10
 20   xrand=x
      return
      end
```